

Insight Racing

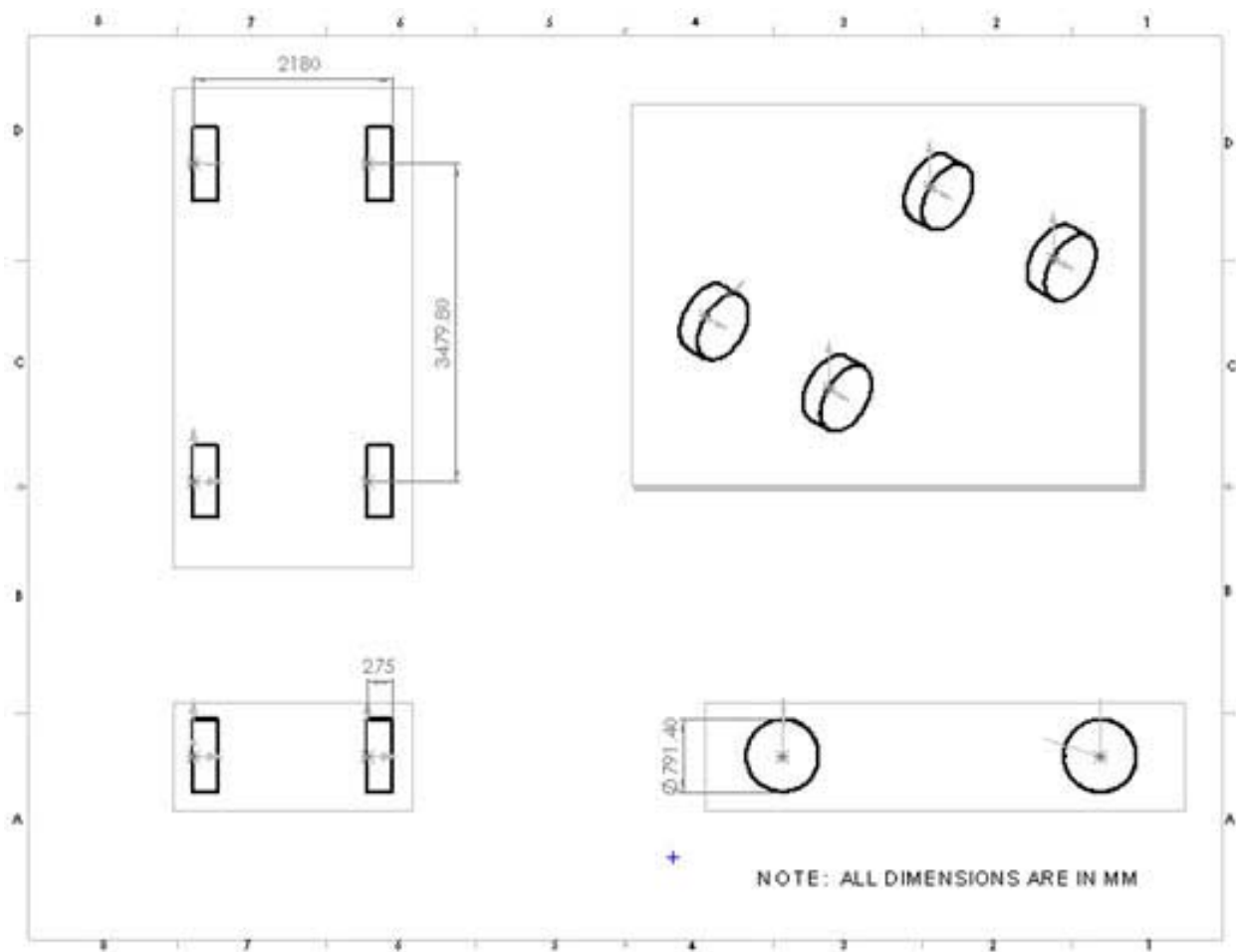
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System Description:

Mobility-

Our base vehicle is a Chevrolet Suburban. Our vehicle's means of mobility is four wheel drive transmitted to the ground through standard rubber truck tires. All four tires are 275/70 R16. The steering is controlled by one gear motor, which drives a sprocket connected by chain to another sprocket mounted on the end of the steering column. The steering inputs are transmitted through a standard steering column, into a gearbox. Tie-rods extending from the gearbox connect to the spindles holding the front wheels. The accelerator and brake pedals are pulled down by steel cables, which run through tubes in the engine bay where two linear actuators are mounted. Speed controllers drive the gear motor and actuators from a 12V DC source. The signal is sent from the computers to the speed controllers via PWM (pulse-width modulation) wires.



Power-

The vehicle is powered by an eight-cylinder, 5.7 liter displacement internal combustion engine fueled by 87-octane gasoline. We will be carrying 66 gallons of this fuel during the race. The peak power consumed by the vehicle is 145,411 Watts.

A separate deep cycle marine battery powers the majority of the added electronic systems. A secondary alternator connected to the engine that produces 14.4 volts and 100 amps

peak recharges this battery continuously. The following table estimates power consumption at normal usage for each device.

Device	Power Usage in Watts
Range Finders (4)	4
Servers (3)	690
Gated View Camera	180
Additional Camera	2.6
BASIC Stamps	.3
Controller Devices	2
Inverter	100
Light	12
Siren	12
POS LV (GPS/INS)	110
Total Estimated Power Consumption	1116

Additionally, a few devices will run off the standard electrical system of the truck. These are outlined in the following table.

Device	Power Usage in Watts
Linear Actuators (2)	134
Gear Motor	120
Total Estimated Power Consumption	254

Processing-

The computing systems involved in our design require the use of 5 computers. One machine will be used for the GPS, INS, and high level routing. Two computers will be used for image processing and one for processing gated laser camera outputs. Then all of these will communicate their information to the control computer.

The computer, which will be used for high level route planning, will use GPS and INS inputs. The device being used contains both GPS and INS internally. It will run off of the INS with updates to the current location using the GPS when available. The specific device is model number POS LV built by Applanix Corporation.

There will be two computers used for image processing to find obstacles and the smoothest path. The first computer will be used for scene analysis and the second one will analyze potential objects for characterization and fine routing control. Scene analysis is looking for large objects, such as trees, buildings, or boulders. Object characterization is used to determine what objects are located in front of the truck within a narrow view.

We shall use a gated laser camera to also scan and attain additional object characterization in front of the truck. This will be processed using a separate computer.

The control computer accepts inputs from the previous 4 computers. These inputs will be evaluated and compared to each other to determine the optimum outputs to be applied to the gas,

brake, and steering. These outputs are communicated through the RS-232 port to a serial to PWM converter. At this point the outputs are sent to speed controllers, which control the movement of the linear actuators, which control the gas and brake pedal as well as the gear motor, which drives the steering column.

Internal Databases-

We plan to use topographical maps, which will be used in the route-planning computer. These will help to determine the best route when facing a large area within boundaries. We will get digital map data from the U.S. Geological Survey (USGS) and from the California Spatial Information Library (CaSIL).

Environment Sensing-

Sensors on our vehicle will include cameras, GPS, INS, range finders, and also a laser system.

We intend to use two different types of cameras in our visual system. The first will include one Cohu 1330 series camera. This will be mounted in the center of the roof near the windshield looking forward. We will use a 35 mm lens to get a wide view of the terrain looking out towards the horizon. The second camera will also be a Cohu 1330 series camera using a 50 mm lens, which will be mounted on the center of the hood. This will be focused to look up to 100 meters in front of the vehicle. We chose the 1330 series because of its "sealed and pressurized environmental enclosure [which] provides maximum protection against rain, snow, dust, ..." This device is also designed to withstand high shock and vibration. Both lenses will be polarized to prevent glare from the sun. To deal with difficulties in calibrating and maintaining calibration of stereo cameras, we have elected to use a single camera image that will be cross-referenced against our gated laser system to establish depth perception.

The cameras will feed a Matrox Meteor frame grabber. The wide view camera image will be processed to look for large objects and used for long range route planning. The shorter-range camera image will be used for making immediate route decisions. The images will be processed by first removing the background colors and then we will enhance any foreground elements into a binary scene. Next we will detect the optimum route of travel based on the clear areas in the picture. The short-range picture will be compared to an image received from the gated laser system to determine the depth of the objects in the pictures. Additional edge processing on the background will be done to look for washouts, holes, or other inconsistencies in the driving surface. By detecting edges in the surface, we expect there are significant changes in the contour of the surface. This will allow us to slow the vehicle and examine the area more carefully. These devices are passive.

The use of GPS and INS will be the primary macro routing tools. This will be used to determine current location, direction, and speed. These will both be contained in the same device. This will provide the primary output from the INS, which is updated by the GPS signals, when available. Therefore, if our vehicle leaves GPS coverage, it will just run off of the INS. When the system loses GPS input for a two-minute time span this unit will still be accurate within

0.60 meters. Other details are provided below. These tolerances will be more than sufficient to stay within a 10 ft course. This is passive.

Laser range finders will be mounted on the front, back, and sides of the vehicle to help determine the amount of room the vehicle can move in each direction. These will prevent us from running into other vehicles and objects. The range finders will be model number LDM 800-RS232 from Laseroptronix and have a range of 4 to 400 meters. They will have a single shot resolution at 200 Hz of ± 1 meter and an averaged resolution at distances less than 100 meters or ± 10 cm. The lasers are class 1, so they are harmless for the eyes. They have a wavelength of 905nm (frequency of 3.3×10^{14} Hz) and a peak power of 20W. These are active.

Our laser system will be a gated laser camera system called the Sea Lynx from Laseroptronix. Because the gated laser system uses a matrix display of individual distance data we can use it to determine range to any object in the field of view of the system. This system can see through snow, rain and fog at a range of 50 to 350 meters and cannot be blinded by bright sunlight like traditional cameras. The system sweeps a laser in a pattern and reads distances then outputs this matrix of points as a grayscale video, which can then be processed by the computer to detect objects and alter the route accordingly. The unit consumes 180W of power and operates at a frequency of 3.66×10^{14} Hz with a maximum output power of 1.2W. The system resolution is 400 TV lines. This system is active.

The sensors are all located inside or attached to the vehicle. The GPS and range finders are attached to the skin of the vehicle. The long-range camera will be mounted above the windshield, in the center of the vehicle, on the roof, while the short-range camera will be located on the center of the hood. The INS will be mounted to the floor of the passenger compartment. The laser system will be mounted on the front of the vehicle.

State Sensing-

Multiple sensors are employed within the vehicle systems to control the motor and actuators. An optical sensor is mounted on the sprocket connected to the steering motor. This sensor detects the presence of gear teeth between the emitter and collector to determine the position of the steering wheel. By counting teeth as they pass through the optical sensor we are able to tell how far the steering wheel is turned left or right. This position can be used in combination with our GPS heading to control the direction of the vehicle. The position of the braking linear actuator is determined by a ten-turn potentiometer. We will use the data gathered about the position of the brake pedal to control the amount of pressure applied to the brakes. Both actuators automatically disengage when they reach the end of their travel due to built in limit switches. The truck's speed is sensed by POS LV. We will also read the signal from the truck's stock fuel sender in order to trigger the activation of the secondary fuel tank.

Localization-

In the routing computer we formulate a line connecting the current route segment. Then based on the current location outputted from the GPS/INS unit, we determine the distance from the line.

In the case of lost GPS signal, we will still receive data from our POS LV regarding current location and other related information. The GPS will automatically update the location in the device when signal is available. As outlined in the table below, without GPS input for a two-minute time span this unit will still be accurate within 0.60 meters. Other details are provided below. These tolerances will be more than sufficient to stay within a 10 ft course. This is passive.

POS LV 320	GPS Outage Duration (IARTK/PP/DGPS)														
	0 sec.			15 sec.			30 sec.			60 sec.			120 sec.		
	IARTK	PP	DGPS	IARTK	PP	DGPS	IARTK	PP	DGPS	IARTK	PP	DGPS	IARTK	PP	DGPS
X, Y Position (m)	0.035	0.02	1.0	0.10	0.05	1.13	0.20	0.06	1.25	0.35	0.15	1.5	0.60	0.40	1.63
Z Vertical Position (m)	0.05	0.03	1.5	0.10	0.07	1.63	0.15	0.10	1.75	0.25	0.20	2.0	0.40	0.50	2.2
Roll & Pitch (deg)	0.05	0.02	0.05	0.05	0.02	0.05	0.05	0.02	0.06	0.05	0.02	0.05	0.05	0.02	0.05
True Heading (deg)	0.05	0.025	0.05	0.05	0.025	0.05	0.05	0.025	0.06	0.05	0.025	0.05	0.06	0.03	0.06

IARTK: Inertially-Aided RTK

PP: Post-processed

DGPS: Real-time Code DGPS

Knowing the valid operational area of the segment defined by the boundaries the routing computer maintains the vehicle position within the operating area at all times. We continuously update the position and compare it to the current line segment determined by the challenge course. The control computer will not allow the vehicle to travel outside the given distance from the line segment.

Communications-

We are not planning to have any external communication devices.

Autonomous Servicing-

We will be carrying enough fuel to avoid re-fueling in the middle of the race and will be filling the tires with fix-a-flat before the race to avoid getting a flat tire.

Non-Autonomous Control-

Before the start and after the completion of the competition the vehicle will perform exactly like a standard vehicle. The vehicle will have a clear area for a human operator to sit inside, where the driver of a traditional vehicle sits.

Since actuation on the brake and accelerator are preformed from the rear of the pedal via a cable system, a driver can override actuation at any time. A human can assume control by simply using the pedals like a normal car.

A driver can assume steering control by adjusting the tilt steering wheel that is found on the vehicle. Steering is performed autonomously by a chain tensioned with the tilt steering function. By adjusting the tilt of the steering wheel, the chain detentions and can be removed. Steering is then performed just as in a standard car, as the steering column has not been modified.



System Performance:

The vehicle has been operated in a clear field. The computer was able to control the operation of the gas, brake, and steering.

The most recent testing was completed on 10/12/2003. During these tests we accomplished better control of the brake, accelerator and steering. These tests involved running the vehicle on both a solid dirt road and in a field that had a loose sand/soil composition that was several inches deep. They also included a section of road that was on an incline and required us to go up as well as down the incline. We are getting ready to install a camera in the vehicle.

Phase 1:

This is the proof of concept phase. The first goal is to manipulate the accelerator, brake, and steering wheel in such a way that we can control movement by the computer outputs. A gear motor and two linear actuators control these components. The gear motor controls the steering wheel via a chain driven sprocket attached to the output shaft and one on the steering column. Cables to the linear actuators, which are mounted in the engine bay, link the accelerator and

brake pedals. The position of the pedals can be controlled by engaging the corresponding linear actuator. After installation of the hardware we created a test program that would allow us to individually control each component.

Once we were convinced that the computer outputs were controlling the motors and actuators correctly we began writing the control application. The next step involved driving the truck from one GPS coordinate to another. This required us to control the steering for direction and the pedals to control the speed. During this stage the current speed and position was based on the output from the GPS system. The current position and the desired position are compared in order to derive the necessary heading and speed.

Estimated Completion Date: 9/20/2003

Phase 2:

The main goal of this stage of the project is to work on object detection and local routing. We intend to use laser radar, inertial navigation system (INS), cameras, and range finders as a means of collecting data concerning the truck's surroundings. The information provided by the systems will be processed within the code to determine the best plan of action according to the current situation.

The gated view uses laser illumination to measure shapes three-dimensionally. This allows the computer to see a three-dimensional view of the terrain ahead of it. This will be used for general detection of large objects in our direct path.

INS allows the computer to determine speed, heading, and position without the use of external signals. It works on the basis of measuring small accelerations then totaling them to determine current status. The INS will work in conjunction with GPS. If either of the systems fails to return a signal, the computer will rely on the active device.

The cameras mounted to our truck will be used for specific object detection. The signals will be sent to the computer for video processing.

The range finders mounted to the sides, front, and back of our vehicle will help the computer determine close range maneuvering. This will also help to detect other vehicles in close proximity.

All of these devices will be used in parallel. The outputs will be deciphered and compared by the control application to determine the proper form of action to be taken by the vehicle.

Estimated Completion Date: 1/1/2004

Phase 3:

This phase includes fine-tuning our computer systems as well as preparing the mechanical aspects of the vehicle for the race. A secondary fuel system will be added in order to increase range. Skid plates and highly modified brush guards will be placed strategically on the outside of the vehicle. Exterior safety devices will also be added.

Estimated Completion Date: 2/1/2004

Safety and Environmental Impact:

Top Speed-

Our vehicle's top speed is fifty-five miles per hour.

Maximum Range-

The vehicle's maximum range, based on the amount of fuel onboard is approximately 460 miles depending on terrain.

Safety Equipment-

Fuel is contained in a Department of Transportation approved fuel tank with breather vents. Warning devices such as a loud speaker that sounds anytime the vehicle starts moving and lights that flash throughout the vehicle's operation will be included.

E-Stops-

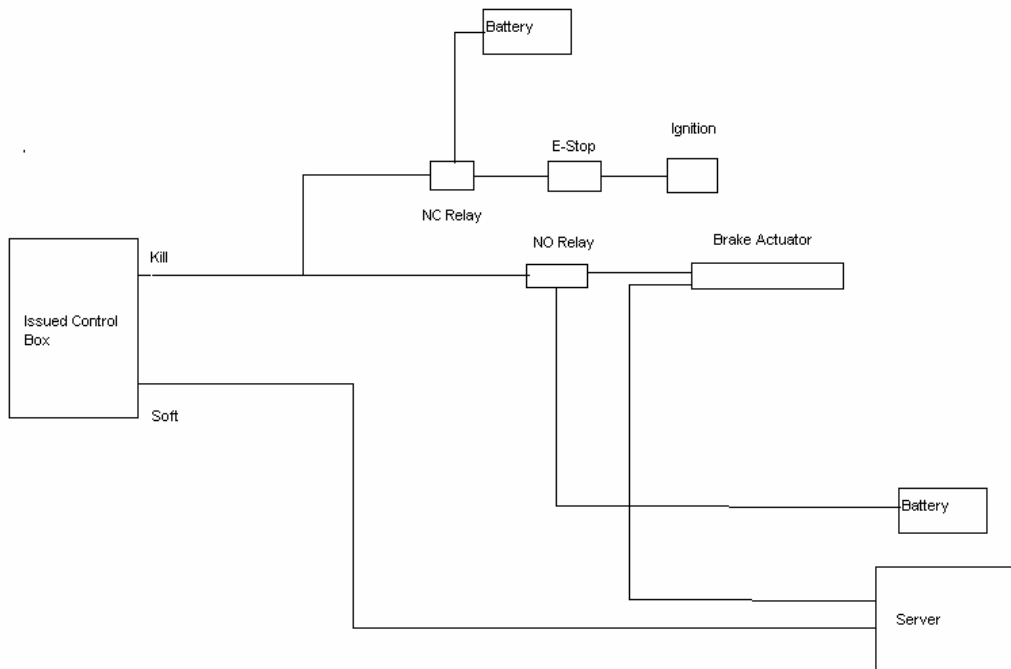
We will use pushbutton switches for emergency stops on this vehicle. They will be push-pull operated, not momentary, so while a kill signal is executed, there will be no chance of accidental startup. It will take a concerted effort to restart the vehicle after it is stopped. Emergency stop switches will be placed on both rear quarter panels of the vehicle.

Hard Stop

The kill stop will be implemented by receiving the kill signal from the emergency stop button or remote stop control. A relay will be in the normally closed position in series with the ignition wires from the steering column. The kill signal will be used to trigger this relay, breaking the ignition circuit. A normally open relay will also be placed on the actuator for the brake, sharing the kill signal that is given from the issued controller. This will be in series with the power to the actuator. The relay will be activated when the hard stop signal is received.

Soft Stop

Two separate stop systems will be used for handling the different stop scenarios. If the software controlled stop signal is sent from the remote monitor, it will be sent into a server. This line will be continuously polled until a true value is found. When the computer recognizes a value on the line, the accelerator will be released to idle, the brake will be actuated in (engaged) and held, and the steering will be returned to the neutral center position. This situation will exist as long as the software recognizes the stop signal.



Placing the vehicle in neutral will be done by reaching in the vehicle and moving the standard column shifter. The vehicle is towable by a conventional tow truck.

Radiators-

The laser range finders will have a peak power of 20W and will be class 1, therefore they will not risk endangering eyes. It will be operating at a frequency of 3.3×10^{14} Hz

The laser gated view system will have a peak power of 180W and will operate at a frequency of 3.66×10^{14} Hz.

All of our lasers are class 1 eye safe lasers and will not be sources of harmful radiation to humans or animals.

Environmental Impact-

The tires may leave tread impressions in the sand, however there is no foreseeable impact to road surfaces. The vehicle is 2 meters wide, 5.6 meters long, and 2 meters tall. The total weight is 2,948 kg. The maximum ground pressure is $26,000 \text{ kg/m}^2$ and the vehicle footprint is 6.53m^2 .

We look forward to hearing your comments and suggestions.

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